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A CASE STUDY on THE EFFECT of an EXISTING LANDSLIDE on DESIGN DECISION and IMPLICATIONS–TAGMotorway,TURKEY

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SUMMARY

A case study on the effect of an existing landslide on the decision for the alignment of TAG Motorway at Kızlaç crossing is presented. The effect of pertaining geological conditions on the choice of proper structure, foundation types and final earthworks and retaining structures are illustrated.

1. INTRODUCTION

So called Kızlaç Region is a critical point along Tarsus-Pozantı-Adana-Gaziantep Motorway due to special geological conditions. Various alignment searches have been carried out to find the most feasible motorway location and the type of the structures (cut, fill, tunnel, viaduct) at this critical passage of the motorway. Considering that the construction has already started at two end of this section, and there are existing structures like E24 road, railroad, pipelines, etc at the same limited area, possible location of the motorway was either the south or the north skirts of the slopes at both sides of the Kızlaç Valley where geology became an improtant factor in the design. A general study covering various alternative routes passing through the northern and southern sides of the valley resulted in a final alignment at the southern side based on the existing level of geological information at the initial design

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stage. Later on, the designer was assigned to perform the preliminary and final design studies following the given alignment. Surface geology and geotechnical surveys consisting of borings, geophysical measurements, laboratory testing, etc. have been immediately started to verify and improve the existing geological information along the alignment. The motorway section starting right after the east portal of Tunnel 2 (fixed point at Km 208+120) and ending at Km 208+700 where the geomorphology becomes flat studied in more detail due to steep slopes and, active landslides. Figure 1 illustrates this critical section on the plan view. The design efforts, steps and decisions for this six hundred meters critical section is the topic of this paper. It is to be noted that the construction of this motorway section was almost completed as a result of below summarized design stages at the time when this paper was under preperation.

2. GEOLOGY and GEOTECHNICAL PROBLEMS

Geology of the area is studied by detailed surface mapping, deep borings and geophysical measurements at preliminary and final design stages in order to verify and if needed revise the existing geological data which was finally used to determine the alignment location and to choose the proper structure and their foundation locations at this critical section. The following geological structure for the area is determined based on this additional study.

Bedrock is partially outcropping and partially covered by variable thickness of dry debris, and has been intersected by all borings between Km 208+120 and Km 208+350. The thickness of the dry debris increases towards the valley bottom and reaches upto thirty meters at some locations. A typical cross section representing the geological structure of this critical area is presented in Figure 2. Ground water is present below the valley bottom level. At this section slopes formed by debris and rock is stable under static loadings at the original topography.

Bedrock is not encountered at two locations due to extensive vertical faulting .These locations are named as Landslide no.1 and Landslide no.2 on the Figure 1. The faults resulted in extensive deformation of the original ground resulting in formation of fault gauge material which is mainly clay with suspending rock boulders. The fault zones are generally fully saturated as observed by surface seepages and springs and form active landslides as noted by continuous deformation of existing structures. Two active existent landslides are separated by rock outcrops as illustrated in Figure 1.

The above described geology was different to some extent than the initial assumptions made by different parties at the initial alignment finalization stage. Therefore, it was essential to reassess the profile of the motorway and the type of the structures to be used

FIGURE 1. VIADUCT V5 - GENERAL LAYOUT

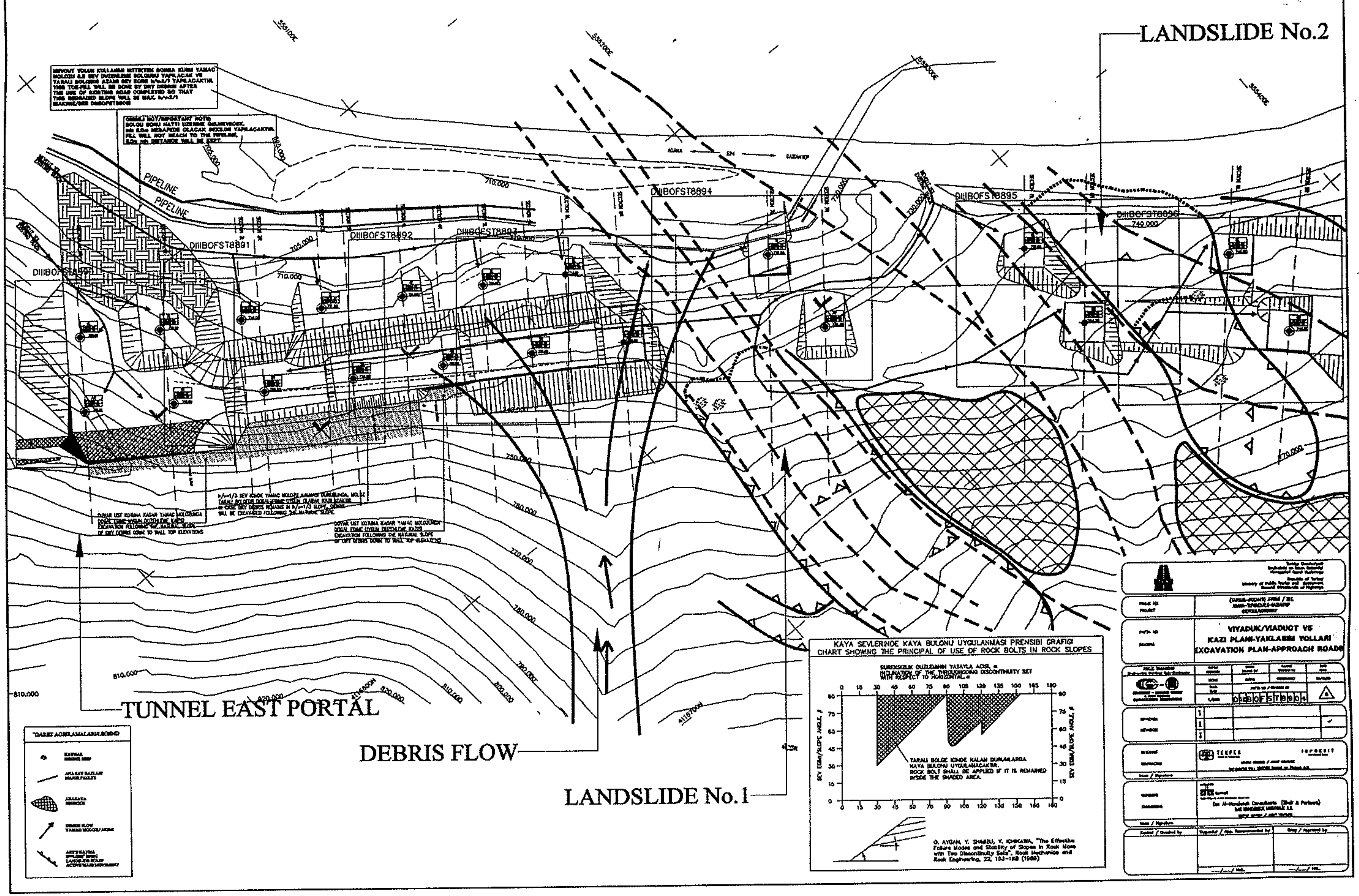
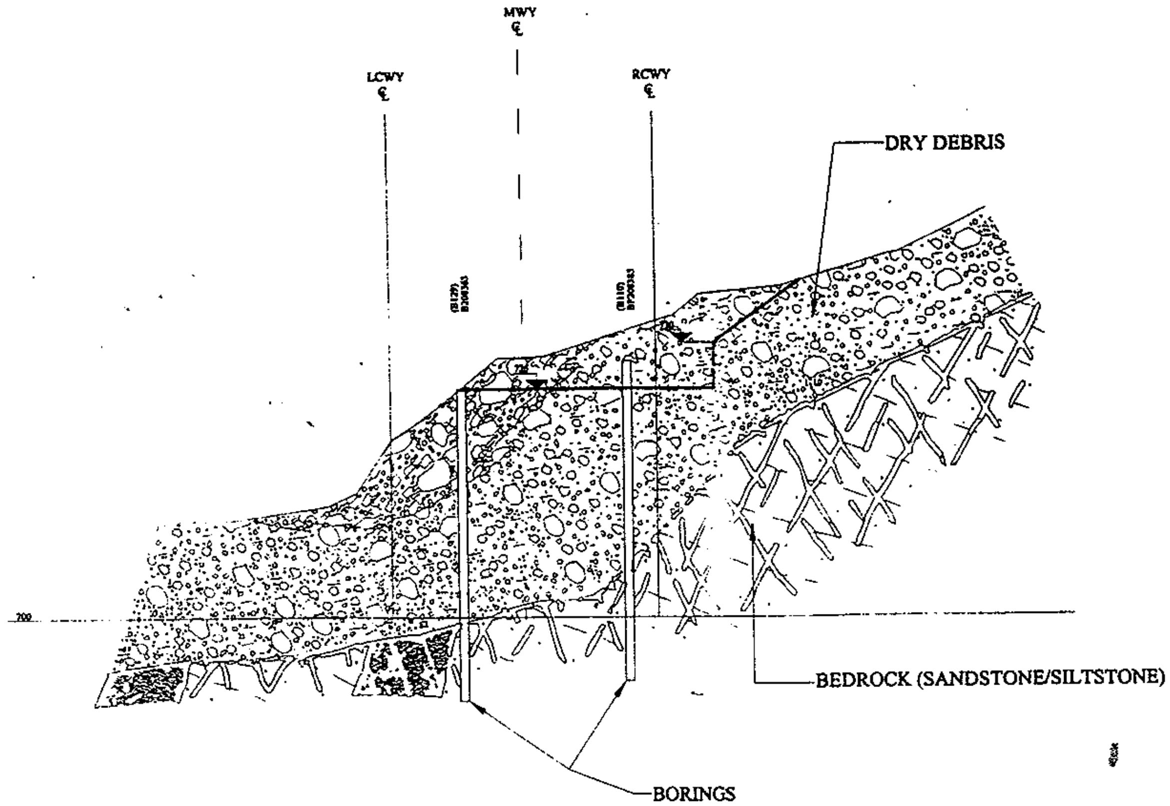


FIGURE 2. TYPICAL CROSS SECTION



to pass the area safely. Additionally, minor improvement of the alignment deemed necessary for the purpose of minimizing the effects of the adverse geological conditions and also to fit the motorway geometrical criteria during the course of the design stages.

3. GEOTECHNICAL APPROACH / STRUCTURE TYPE

This section of the motorway is evaluated in detail for the purpose of determining the most proper structure type considering the variable and critical geotechnical problems of the area. The following steps are taken during decision making .

Sections with bedrock covered by dry debris Figure 2 are stable under static conditions at the natural geometry. However, sensitivity analysis showed that such a soil profile is not stable under earthquake condition and adverse earth movements also as a result of adverse earth movements. Therefore, it is considered that the best solution would be the one with the least earth movements and to relay on the strong and stable bedrock conditions. Sections coincident with the activelandslide areas are difficult for all kinds of structures. Therefore, it is considered that the best solution would also be the one with no interference with lanslide zones by major structures.

After various comparison studies, it is considered that viaduct structure for the complete critical section would be the most feasible solution. The viaduct structure type is recommended as conventional reinforced concrete with prestressed reinforced concrete beams, approximately 36.0 m long for the initial portion of the section from Tunnel 2 east portal (abutments A) to Pier 6 where there is no landslide interference. From Pier 6 to abutment B where landslides hinder the stability of the area, the viaduct structure is recommended as steel deck on reinforced concrete piers in order to overpass the critical zones with longer spans which would not be possible with a conventional reinforced concrete deck. Three steel spans of 90, 110, 90 m long is used between Pier 6 and abutment B. The locations of the piers are selected such that piers, thus foundations are sufficiently away from landslides, but also follow the systematic span lengths as a whole so that the superstructure is also optimized.

General layout of the viaduct structure together with the geology and geometry of the area is illustrated in Figure 1. Six reinforced concrete spans and three steel spans are designed to pass the critical section between east portal of Tunnel 2 (Km 208+120) and Km 208+700. The profile of the viaduct is mostly determined by the fixed level at the tunnel 2 east portal.

4. VIADUCT FOUNDATIONS and EXCAVATION PLAN

The viaduct foundations especially to determine the foundation elevations and required excavation limits are studied and presented in this section of the paper. The retaining structures that will be required to provide appropriate working platforms for the foundations and to satisfy slope stability without interfering with the landslide areas will also be presented.

Results of the performed stability analysis are sufficient to conclude that the static factor of safety of the slope, although above unity does not satisfy the minimum factor of safety of 1.50. The analyzed section at Km 208+140 presents the most unfavorable geometric conditions for the section up to Km 208+340 (Pier 6) where dry debris is encountered, thus, similar regrading and supporting works are proposed for the section between Piers 1 to 6. The regrading is proposed for the whole section (not only at pier locations) until Pier 7 to increase the stability of the dry debris slopes.

Slope stability analysis show the positive effect of the drainage by subhorizontal drains. Drain length of 40.0m to 50.0m is required to have sufficient decrease in the ground water levels. In addition to this deep drainage system, some surface drainage especially around the landslides by concrete lined ditches and trenches will be required.

4.1. Main Considerations in the Selection of the Excavation Levels

The section of the viaduct V5 with concrete spans between Abutments A and Piers 6, is recommended to be regraded in a general manner not only at pier locations due to the slope stability requirements. The foundations of this viaduct section should not be subject to any lateral loads due to instability of the hillside. Therefore, the stability of the slopes formed with dry debris above bedrock (refer to the geological section) along this section of the viaduct should be thoroughly satisfied under static and earthquake conditions.

The foundation excavations for the piers of viaduct V5 with steel spans between Piers 6 and Abutment B, is recommended to be separate and as limited as possible in order not to interfere with the landslide areas. For this purpose, retaining structures will be required at the foundation locations as illustrated by the enclosed plans a minimum platform size of 15.0m x 15.0m is provided at all pier locations, in order to have sufficient and appropriate working platform for the machinery and also enough space for the foundation caps.

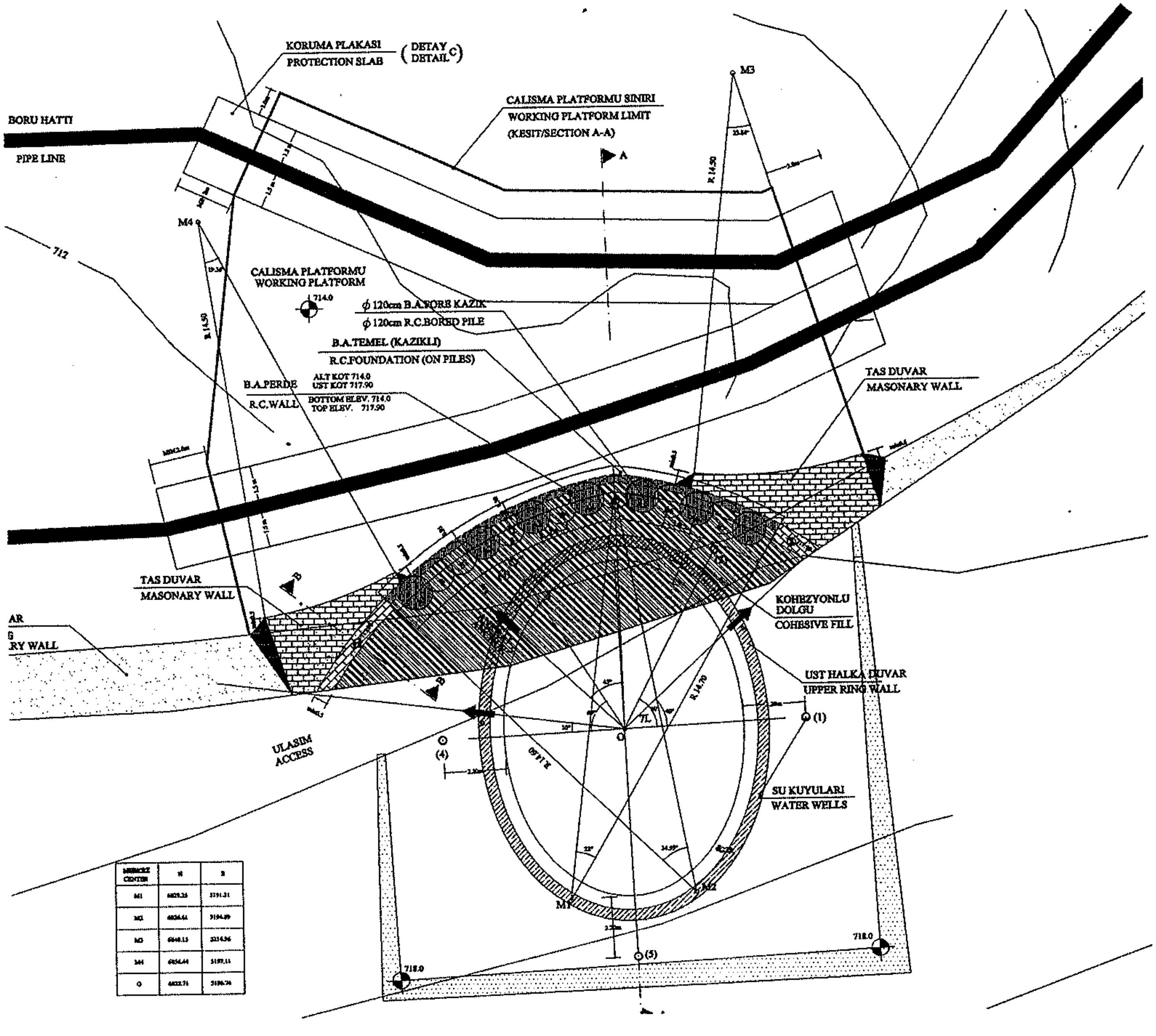
The elevation difference between foundations of the two carriageways are aimed to be minimized so that the free excavation without any requirement for supporting systems will be sufficient between the carriageways. The free excavation slope in dry debris is taken as h/v=3/2 and that in rock (with some surface protection) is taken as h/v=2/3.

At the right side of the right carriageway between Abutments A and Piers 6, where a general regrading is recommended, the excavation levels and distances from the motorway are selected such that the rockline will be caught with sufficient confidence and thus, instead of dry debris slope, steeper and more stable rock slopes will be treated.

The interference with the pipeline is another constraint. In this respect Pier 7L is the most critical one. It is not favored to have any fill or any excavation onto or close to the existing pipeline. Therefore, the excavation elevation for pier 7L is recommended as 718.0m as indicated on the plans and cross-sections see Figure 3. At this pier location, the caisson excavation will be carried out with sufficient peripheral supporting so that no major deformation/stress will be imposed to the pipeline.

The final constraint in the selection of the foundation bottom levels is that all the piers will have a smooth variation of the pier heights without any abrubt change between piers so

FIGURE 3. LAYOUT OF CAISSON 7L.



that an even distribution of the lateral loads to piers could be achieved. In fact, the present foundation elevations chosen are also complemented by the superstructural design group.

4.2. Proposed Foundation Types

All the piers carrying the steel spans are proposed to be onto caisson foundations with sufficient depths. The caisson size considered as 10.0m circular in the early stage is modified to 8.0m by 12.0m eliptical form due to various benefits obtained from eliptical form. Eliptical caissons can be oriented so that minimum lateral load will be faced from the landslides and maximum moment of inertia against lateral loading of the landslide will be attained. Additionally, the rectangular cellular pier proposed by the superstructural group will geometrically fit to the lower caisson dimension so that a major foundation cap will not be required.

All the other piers carrying the concrete spans are also proposed to be on to deep foundations. Φ165cm piles were proposed for these piers in the previous studies. However, the boring investigations at the area indicate the difficulty of drilling through the eratic quartzite boulders. Additionally, it may not be possible to provide the required socketing of piles into the bedrock with sufficient confidence of the site engineers and with sufficient construction quality. All these considerations lead to the proposal of caisson foundations for the other piers as well. The caissons for the concrete spans are in 6.0 meters diameter and a much simpler peripheral supporting by wiremesh and shotcrete during excavation will be sufficient in comparison to the eliptical large caissons proposed for the steel spans.

As an exception, elliptical caissions are used for abutment A which carries a reinforced concrete deck due to the reason that geometry of an elliptical caission fits better to the geometry of the abutment. In this case, one caisson under each pier was sufficient, thus, interference between nearby caissons were eliminated during construction activities and also full capacity of the caissons could be utilized.

The followings were observed during the manually excavated construction of caissons:

- Circular caisson could be excavated by wiremesh+shotcrete lining without any special support down to 35.0 m in debris+bedrock, of course, with sufficent drain holes avoiding the accumulation of water behind the lining.

- Production rate for the circular caissons was quite high indicating that the engineering decision of manual excavation against piling was a proper choice.

- Elliptical caissons, however, required some additional supports especially for the flat portion of the ellips. As a result, prestressed anchors are used at every excavation stage to support the lining through an inner beam.

- Figure 4 shows the typical support system section utilized for the elliptical caissons. Anchors, are used only down to bedrock, wiremesh+shotcrete lining was sufficent in the bedrock without any additional support system.

- It is important to note that all caissons are sufficiently embedded to bedrock so that under superstructural loads (especially under earthquake case), deformations of the caisson would be in tolerable limits given by the structural designer.

- It is also an important benefit of the elliptical caisson that, elliptical shape of the caisson permitted minimum face area interfered with the landslide zones since narrow side is perpendicular to the landslide direction.

- Due to the reason that, the soil conditions could be visually inspected at the sides and bottom of the caisson during excavations, exact bedrock levels and the most proper finishing level could be determined with high confidence with the selected system.

- The caisson reinforced concrete structure is designed in terms of reinforcement to carry the superstructural loads and the concrete pouring is realized in steps from bottom to top under controlled conditions leading to a high quality structure.

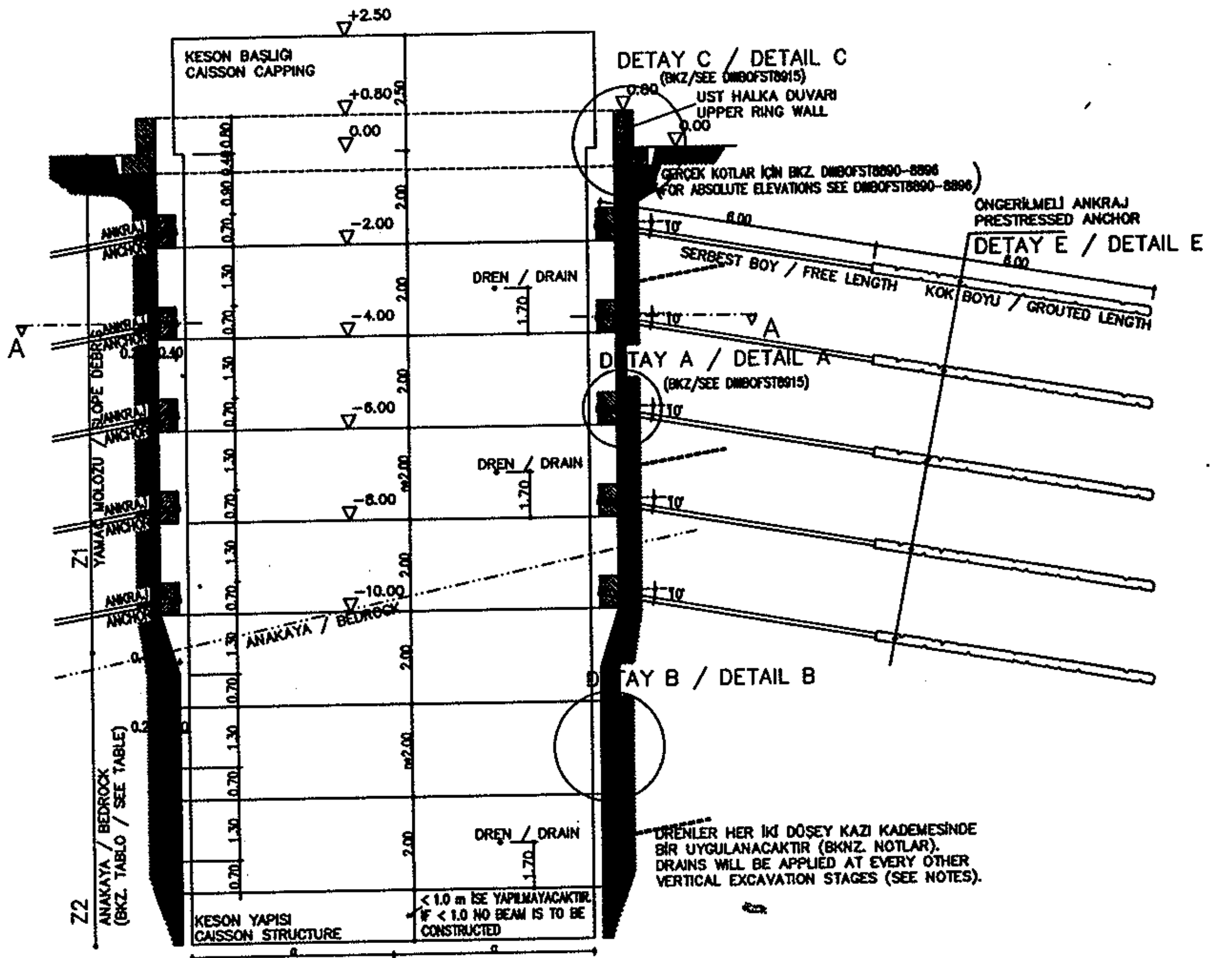
5. RETAINING STRUCTURES

There are two different types of retaining structures to be considered for the foundation excavations of viaduct V5 as discussed below.

5.1. Retaining Wall Between Km 208+140 and Km 208+200

The first wall type is between Km 208+140 and Km 208+200 on the right side of the motorway combined with the perpendicular wall at Km 208+140 and the portal support system. In the previous studies, anchored pile was recommended for this wall. However, due to the fact that the latest studies show a rock line closer to the surface than previous

FIGURE 4. SECTION OF CAISSON 7L.



ÖNEMLİ NOT:
KESON TABANINDA SAĞLAM KAYA GÖZLEMLE TESBİT EDİLECEKTİR. AKSİ TAKDİRDE KESON BOYU MÜHENDİS ONAYI İLE UZATILACAKTIR.

IMPORTANT NOTE:
SOUND BEDROCK WILL BE OBSERVED AT CAISSON BASE IF NOT, CAISSON LENGTH MAY BE INCREASED WITH APPROVAL OF ENGINEER.

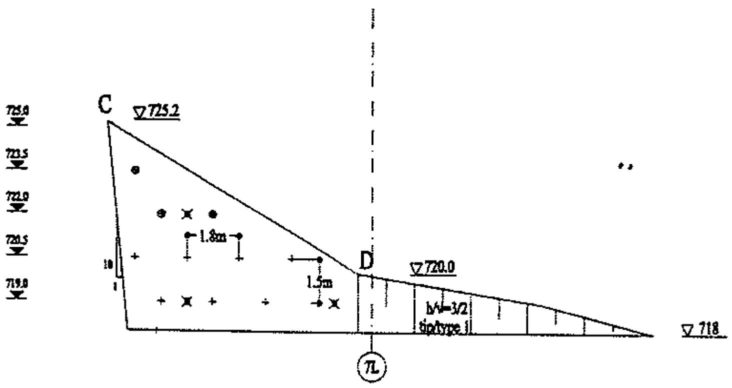
assumptions and due to the large-diameter drilling difficulties, pasive anchored wall (soil nailed wall) is recommended for the final design.

This wall is expected to be some 18.0m high at Km 208+140 above the expected rock line. The distance of this wall from the motorway centerline (38.0m) is selected such that the dry debris thickness will be minimized and the total excavation volume will be optimized. Calculations carried out for this wall for the wall height of H=18.0m indicate that a grid of 1.5mx1.5m will be sufficient for the pasive anchors with UTS 835/1030 Φ26 bars. The wall surface will be conventional wiremesh + shotcrete.

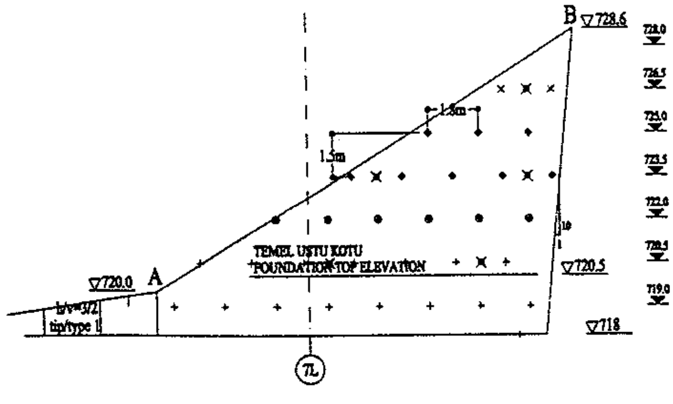
5.2. Retaining Walls for the Foundation Pits

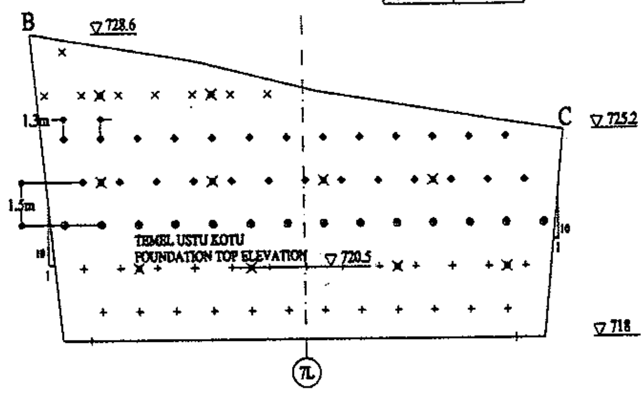
Some foundation pits have to be supported by retaining walls in order to avoid interference with landslide areas and also to limit the excavation slopes between nearby piers. Cantilever pile walls were recommended for such foundation pits in the previous studies. However, due to the fact that piling is recommended to be avoided at viaduct V5 location, pasive anchored wall-soil nail wall is recommended also for the single foundation pit excavations at the final design stage. The typical foundation pit supported with soil nails is given in Figure 5.

FIGURE 5. SUPPORT OF CAISSON 7L EXCAVATION BY NAILING.



PASIF ANKRAJ KONFIGURASYONU PASSIVE ANCHORAGE CONFIGURATION			
ISARET LEGEND	UZUNLUK/LENGTH	ADET QTY	TOPLAM TOTAL
+	4.0 m	48	192
●	5.0 m	61	305
◆	6.0 m	34	204
×	7.0 m	8	56
△	8.0 m	0	0
○	ANAKAYAYA min 3.0 m GIRECEK SOCKET TO BEDROCK min 3.0 m	0	0
✖	DREN (BKZ DIIIBOFST8903) DRAIN (SEE DIIIBOFST8903)	26	
		TOPLAM TOTAL	757





6. SUMMARY and CONCLUSIONS

This paper presents the design steps taken for the viaduct V5 constructed at the critical Kızlaç Passage of TAG Motorway. It is important to note that how soil conditions and local geology could be effective for the decision process of the selection of the proper system for the construction of a motorway section as examplified by this case study.

It is demonstrated that the choice of correct engineering solutions and proper structure types are essential for the protection of the motorway from the potential major hazards. In this case, detection of landslide zones prior to the design and as a result avoiding detrimental effects of such critical zones by proper locationing and choice of the viaduct structure and its foundations reduced the efforts and risks for the construction and service life of the motorway in this section.

Information is also provided for the foundation systems selected for this case. It is interesting to note that sometimes manual constructions could be more feasible against machine utilized conventional methods as utilized in this case according to the existing soil conditions.

ACKNOWLEDGEMENT

This paper is a small part of an extensive studies performed by different groups at different stages for the finalization of the alignment of TAG Motorway near Kızlaç Village. The geological and geophysical site studies which led to correct engineering solutions were carried out within the scope of studies performed by Geoconsult, Austria. The engineering solutions for the choice of proper structure, foundations and design implications such as excavation supports, drainage etc. were developed by the Design Group GEOCONSULT ZT GMBH-ZETAŞ Earth Technology Corp. and were critically reviewed by the Engineer TEMAT-Dar AL – Handasah Consultants – Dar Mühendislik J.V. The Turkish General Directorate of Highway Department -KGM were actively participated and contributed in critical meetings to reach the final choice of the design. All of the works are carried out under the direct coordination of the Contractor Tekfen Impresit J.V. Authors are very thankfull for all above parties involved in the studies for their kind support.